Copy 6
RM E52E14

NACA RM E52E14

NACA

RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF EFFECT OF ANGLE OF ATTACK ON PRESSURE RECOVERY AND STABILITY CHARACTERISTICS FOR A VERTICAL-WEDGE-NOSE INLET AT MACH NUMBER OF 1.90

By L. Abbott Leissler and Donald P. Hearth

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON
August 12, 1952

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION OF EFFECT OF ANGLE OF ATTACK ON PRESSURE RECOVERY AND STABILITY CHARACTERISTICS FOR A VERTICAL-WEDGE-NOSE INLET AT MACH NUMBER OF 1.90

2533

By L. Abbott Leissler and Donald P. Hearth

SUMMARY

A preliminary investigation of a wedge-type compression surface mounted vertically in a circular cowling was conducted in the Lewis 18- by 18-inch supersonic wind tunnel at a Mach number of 1.90 and at angles of attack from 0° to 10°.

With a symmetrical cowling, pressure recovery and stability characteristics comparable to a conical inlet were obtained; however, twin-duct flow interaction was observed. Modification of the inlet by cutting back the lower cowl lip and by perforating the wedge centerbody reduced slightly the pressure recovery at zero angle of attack but resulted in constant maximum pressure recovery up to an angle of attack of 10°. These modifications also eliminated the twin-duct instability and increased the stable subcritical range of the inlet.

INTRODUCTION

Investigations of cone-type compression inlets (references 1 to 4) show a marked decrease in the maximum pressure recovery and mass flow when the inlet is operated at angles of attack comparable to those encountered in maneuvering flight. Such decreases in maximum pressure recovery may result partly from a thickening of the boundary layer on the lee side of the conical spike because of the uneven supersonic compression associated with a cone when at angle of attack. The use of a vertical wedge as the compression surface should prevent such uneven compression and therefore might cause the maximum pressure recovery of the inlet to be less sensitive to changes in angle of attack. Furthermore, as is suggested in reference 5, the operation of a wedge-type compression surface in a circular cowling may have superior stability characteristics subcritically because, as the mass flow is decreased, the vortex sheet (see reference 6 for further discussion) intersects only a small segment of the cowl.

An investigation was therefore conducted in the 18- by 18-inch supersonic wind tunnel at the NACA Lewis laboratory on an inlet of circular cross section having a vertical wedge compression surface. Pressure recovery and mass-flow characteristics were evaluated at a free-stream Mach number of 1.90 and at angles of attack from 0° to 10°. The Reynolds number (based on wedge height at the leading edge) was 5.25×10^5.

SYMBOLS 2533

The following symbols are used in this report:

m mass flow

P total pressure

α angle of attack

Subscripts:

0 free stream

3 station at pressure rake

m maximum

APPARATUS

The model was mounted in the tunnel as shown schematically in figure 1. Measurement and control of the mass flow through the inlet was by means of an orifice and butterfly-valve combination which yielded mass-flow data accurate to ±3 percent. The pressure recovery was measured with a total-pressure rake, while variation in angle of attack was obtained by rotating the support strut.

The original inlet consisted of a wooden wedge having a 34° included angle mounted in a metal cowl which was formed by joining a 3.6-inch-diameter cylinder to a 30° truncated cone (fig. 2). The metal fillers shown were mounted in the region where the wedge meets the conical part of the cowl in order to prevent any expansion in that portion of the supersonic diffuser. The cowl lips were sharpened to a knife edge and swept back along the oblique shock.

The second configuration tested (fig. 3) consisted of the original inlet with the following modifications: First, the lower half of the cowl lip was removed and the leading edge thus exposed was rounded;

secondly, the wedge was perforated by drilling a series of 1/8-inch-diameter holes so that the first row of holes was located just downstream of the normal shock for critical flow conditions and the last row of holes approximately 1.4 diffuser exit diameters further downstream. The total area of the holes was 13.6 percent of the cowl entrance area. Subsonic area variation for the two configurations is shown in figure 4.

2533

RESULTS AND DISCUSSION

With the original inlet installed so that the wedge was vertical, pressure-recovery and mass-flow data were obtained at angles of attack from 0° to 10°. These data, as presented in figure 5, show that the maximum pressure recovery decreased from 0.86 to 0.76 as the inlet was taken from 0° to 10° angle of attack. Because the instrumentation was insufficient to indicate the onset of unstable flow, the minimum stable point was assumed to be that point at which maximum pressure recovery was observed (see reference 7). From figure 5, a stable range comparable to the conical inlets reported in reference 6 is apparent. During unstable operation, however, asymmetric flow, which would indicate a twin-duct form of instability, was observed.

The reduction in pressure recovery when the inlet is at angle of attack may have been caused partly by either flow separation from the inside of the lower cowl lip or by expansion of the flow in this region. As a possible means of improving angle of attack performance, the lower half of the cowl lip was cut away. At the same time, the leading edge of the lower half of the cowl was rounded to reduce separation of the entering flow at angle of attack.

In reference 8, an analysis was made of twin-duct flow interaction and it was concluded that this phenomenon is a function of the static-pressure recovery at the juncture of the two ducts. Equalizing the static pressures in the two ducts should therefore eliminate the asymmetric flow. In order to equalize the static pressures, the wedge was perforated as previously described.

The performance of the inlet with the perforated wedge and the lower lip cut away is presented in figure 6. Although the modifications caused a decrease of 1.3 percentage points in the maximum pressure recovery at zero angle of attack, only a slight variation in pressure recovery resulted as the inlet was taken from 0° to 10° angle of attack. The removal of the lower lip caused approximately 7 percent flow spillage at zero angle of attack. In contrast to other inlets, there is, however, an increase in mass flow as the inlet is raised to positive angles of attack because of increasing cowl entrance area.

Visual observations of the modified inlet during unstable operation indicated that the asymmetric flow was avoided. The solid lines in figure 6 indicate at all angles of attack a fairly large stable subcritical range in which the pressure recovery remains relatively constant.

Although this particular inlet was not run at negative angles of attack, an investigation of a similar inlet with the lower half of the cowling removed indicated a decrease in pressure recovery at negative angles of attack approximately the same as that observed before the 2533
lower lip was removed.

A comparison of maximum pressure recovery at angle of attack expressed as a percentage of maximum pressure recovery at zero angle of attack for the vertical wedge configurations investigated is shown in figure 7. Included is the variation for a typical conical spike inlet. The loss in pressure recovery with angle of attack for the original inlet is greater than that for the conical spike inlet shown; however, the modifications resulted in relatively constant pressure recovery up to 10° angle of attack.

SUMMARY OF RESULTS

The following results were obtained from an investigation of an inlet composed of a wedge mounted vertically in a circular cowling. Data were obtained in the Lewis 18- by 18-inch supersonic wind tunnel at angles of attack from 0° to 10° and at a Mach number of 1.90.

1. Pressure recovery and stability characteristics for the original inlet were comparable to a conical spike inlet; however, during unstable operation, twin-duct instability was indicated.

2. With the lower cowl lip removed and the wedge centerbody perforated, essentially constant maximum pressure recovery was obtained from 0° to 10° angle of attack. Although some flow spillage was introduced by removal of the lower lip, the amount of spillage was reduced as the inlet was raised to positive angle of attack. These modifications also eliminated the twin-duct instability and increased the stable subcritical range of the inlet.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio

REFERENCES

1. Perchonok, Eugene, Wilcox, Fred, and Pennington, Donald: Effect of Angle of Attack and Exit Nozzle Design on the Performance of a 16-Inch Ram Jet at Mach Numbers from 1.5 to 2.0. NACA RM E51G26, 1951.

2533

2. Englert, Gerald W., and Obery, Leonard J.: Evaluation of Five Conical Center-Body Supersonic Diffusers at Several Angles of Attack. NACA RM E51L04, 1952.

3. Brajnikoff, Gerald B., and Rogers, Arthur W.: Characteristics of Four Nose Inlets as Measured at Mach Numbers between 1.4 and 2.0. NACA RM A51C12, 1951.

4. Anon: Free-Jet Tests of 7.81-Inch Model of the XSSM-N-6 Ramjets. Project Rigel Missile, Ordnance Aerophysics Lab., Marquardt Aircraft Co. May 23 to June 3, and Sept. 19 to 23, 1949. Rep. No. A-30, Grumman Aircraft Engineering Div. (BuAer Contract NOa(s) 9403).

5. Anon: Development of Ramjet Components. Prog. Rep. No. 9961-12, Univ. of Southern Calif., Aug., Sept., and Oct. 1950. (Navy Research Project Contract NOa(s) 9961).

6. Ferri, Antonio, and Nucci, Louis M.: The Origin of Aerodynamic Instability of Supersonic Inlets at Subcritical Conditions. NACA RM L50K30, 1951.

7. Sterbentz, William H., and Evvard, John C.: Criterions for Prediction and Control of Ram-Jet Flow Pulsations. NACA RM E51C27, 1951.

8. Martin, Norman J., and Holzhauser, Curt A.: Analysis of Factors Influencing the Stability Characteristics of Symmetrical Twin-Intake Air-Induction Systems. NACA TN 2049, 1950.

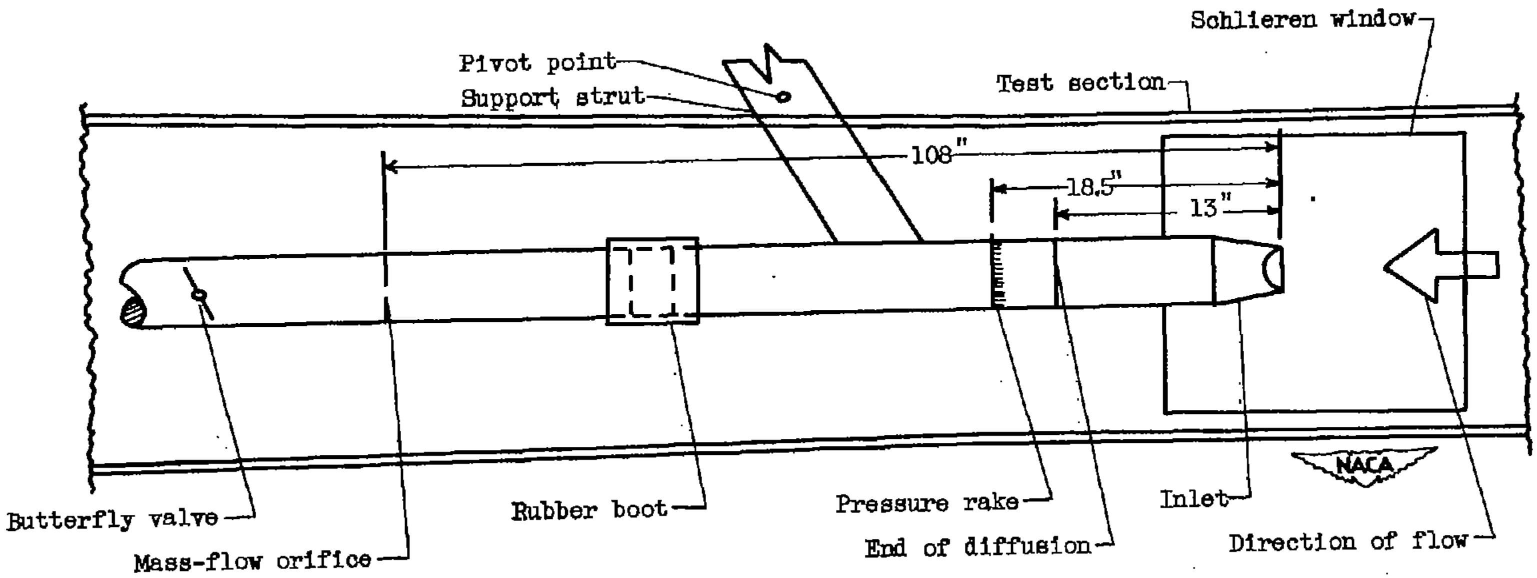

Figure 1. - Schematic diagram of installation.

2533

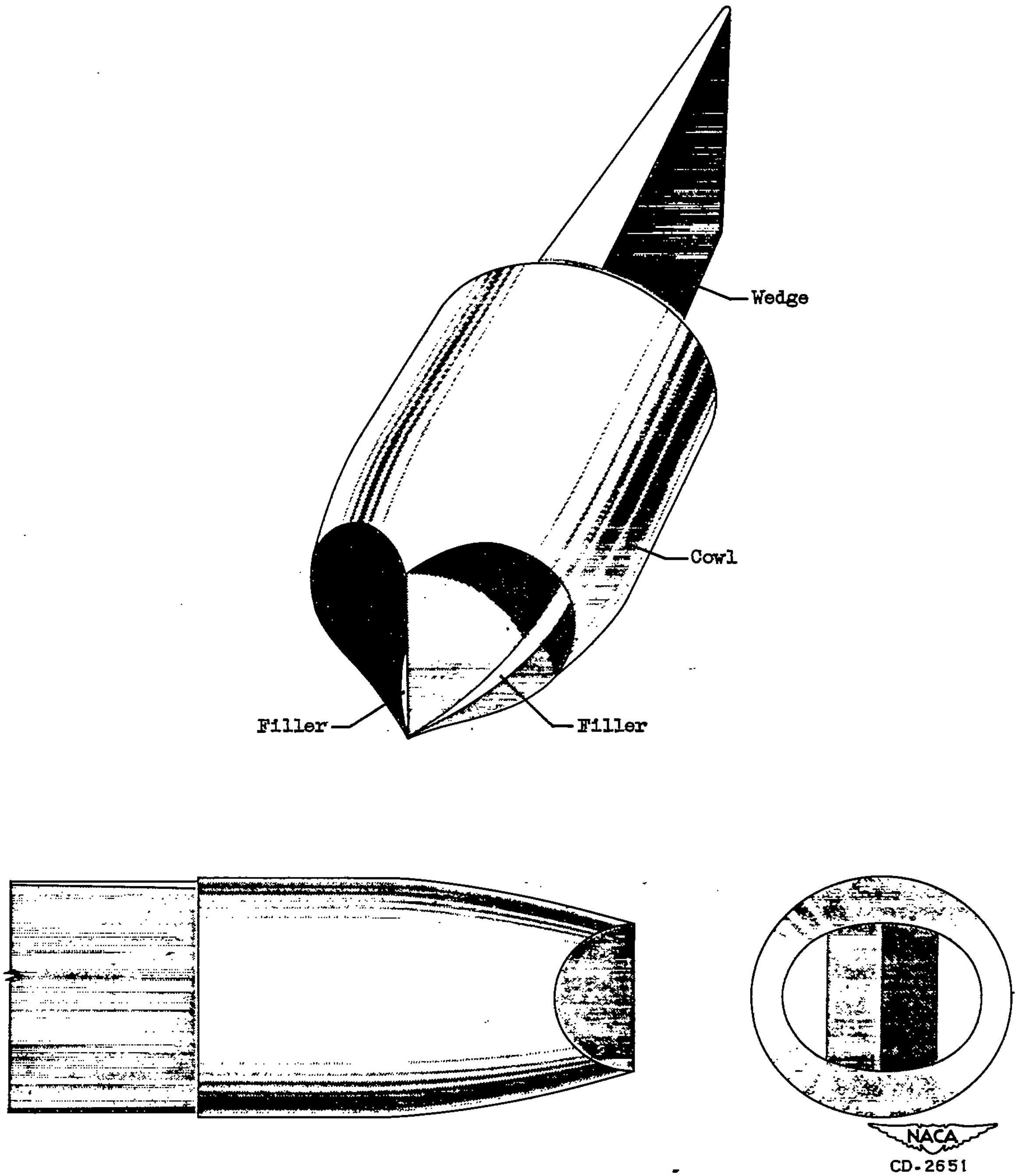

Figure 2. - Original inlet.

[redacted]

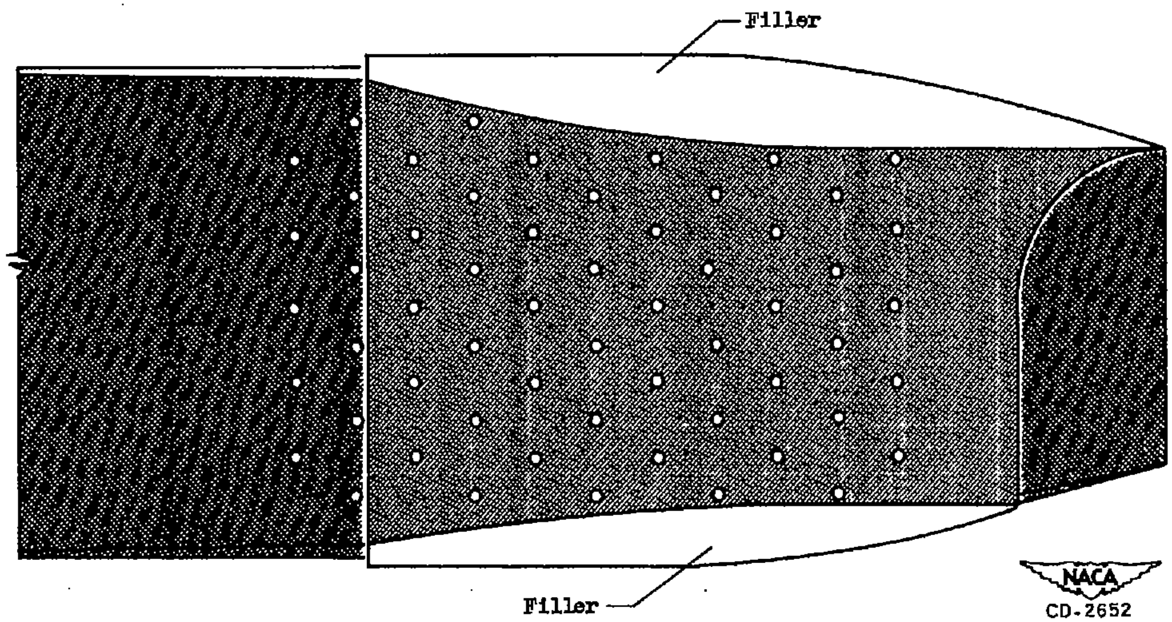

Figure 3. - Side view of modified inlet.

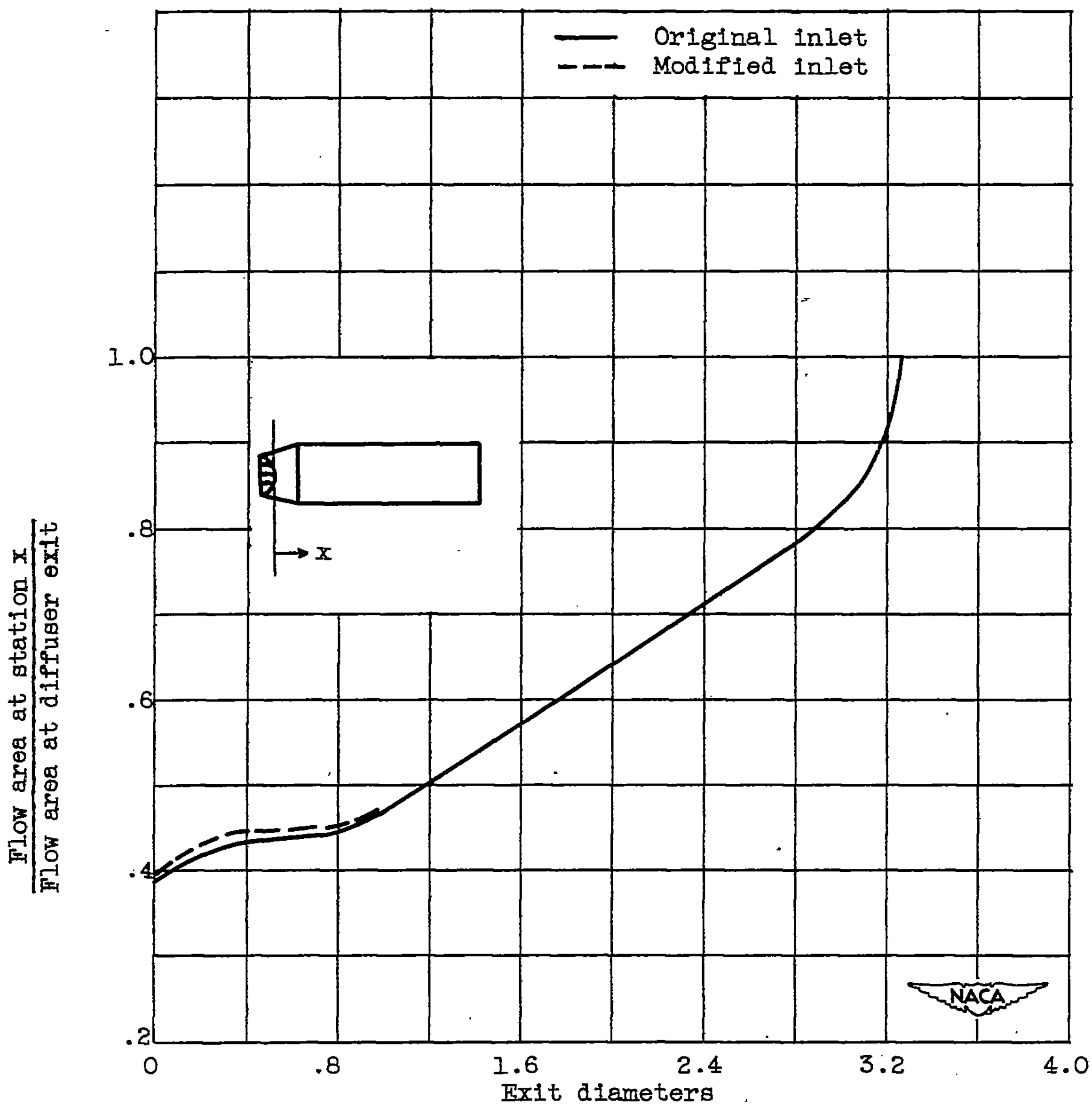

Figure 4. - Diffusion rate of vertical wedge inlets.

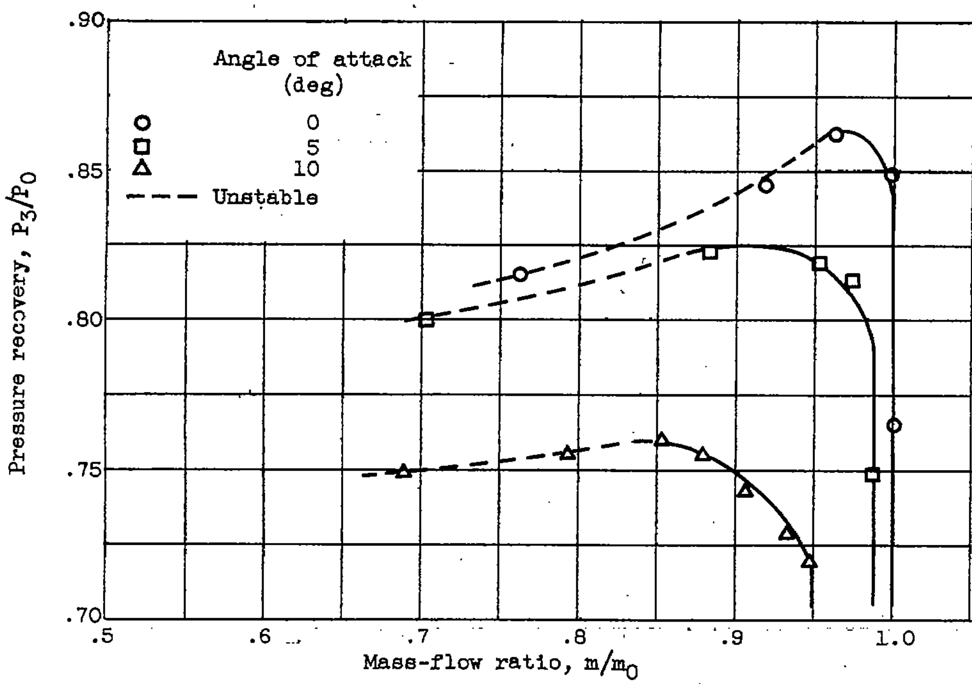

Figure 5. - Effect of mass-flow ratio on pressure recovery for original inlet.

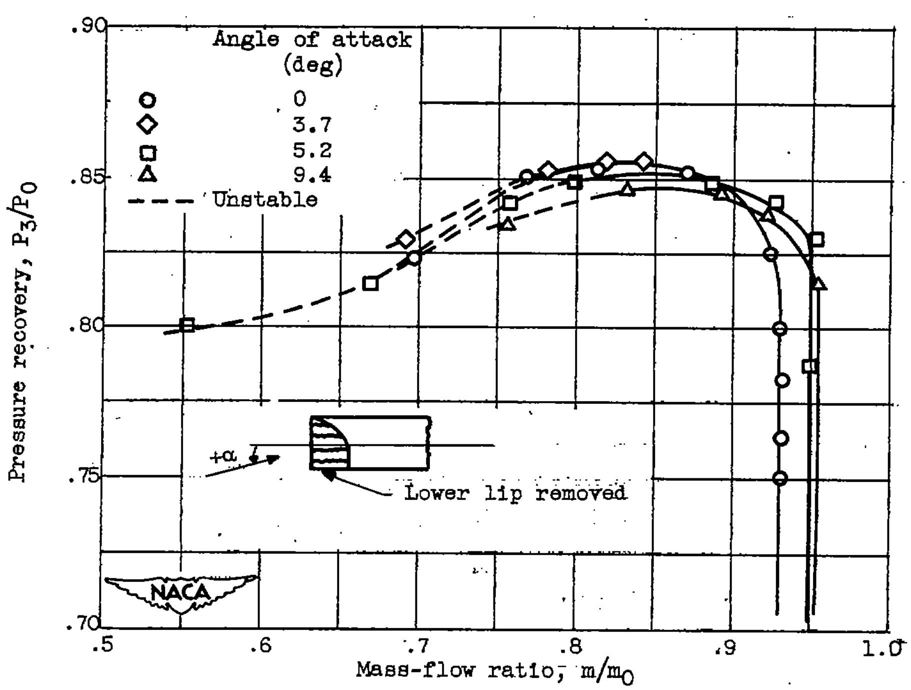

Figure 6. - Effect of mass-flow ratio on pressure recovery for modified inlet.

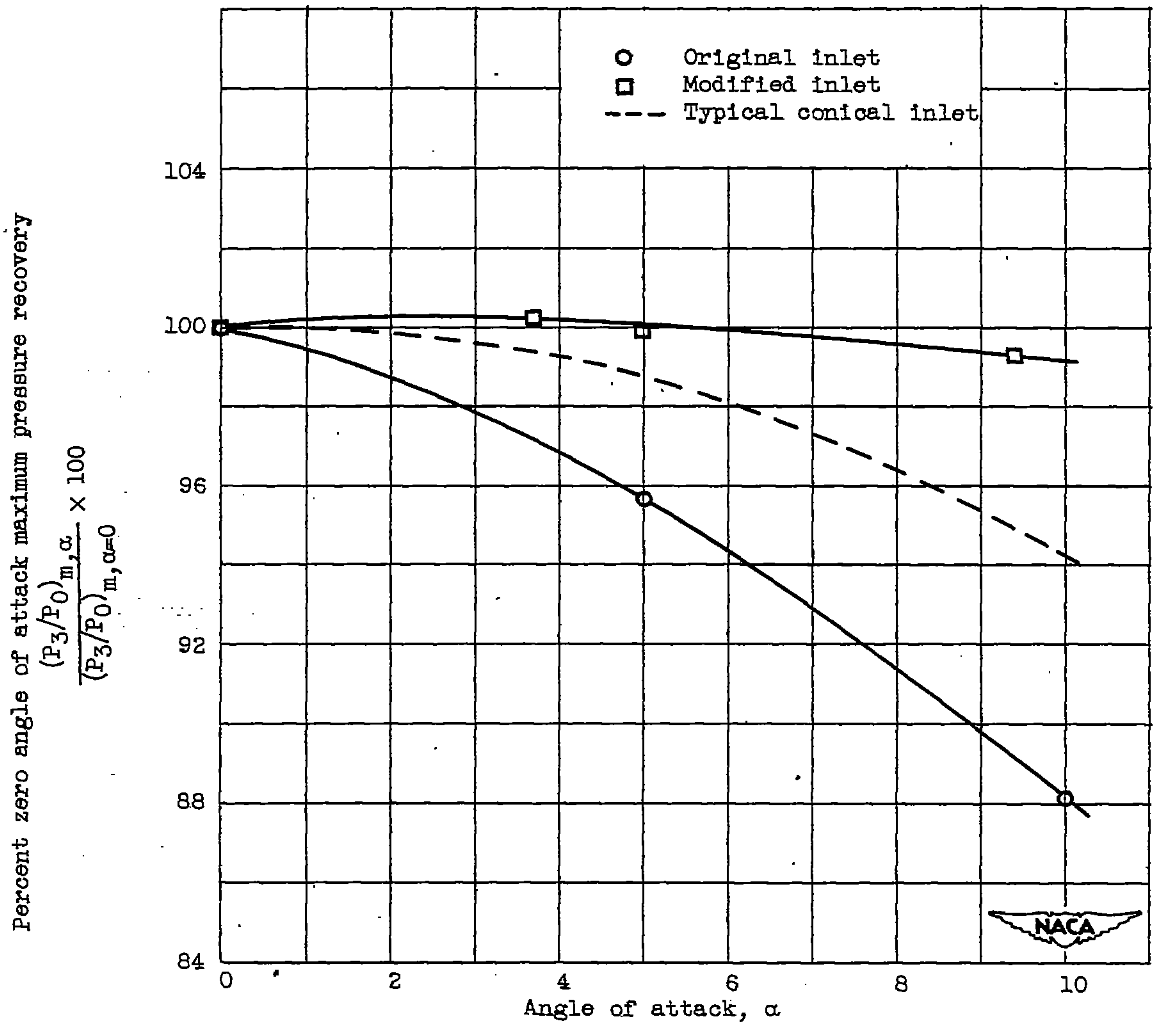

Figure 7. - Effect of angle of attack on percentage of zero angle of attack maximum pressure recovery.

~~SECURITY~~ INFORMATION

[redacted]

[redacted]